National Park Service
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Natural Resource Program Center
Fort Collins, Colorado

Invasive Exotic Plant Monitoring at Pipestone National Monument

Year 2 (2009)

Natural Resource Technical Report NPS/HTLN/NRTR—2010/294

ON THE COVER
Prairie with Sioux quartzite outcrop and woodland in background at Pipestone National Monument.

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Abstract

During surveys in 2006 and 2009, we documented a total of 20 invasive exotic plant taxa in Pipestone National Monument. All species were previously known to occur in the park. We found three grass species to be widespread and abundant: bluegrass and smooth brome were each estimated to cover at least 21 acres or more on the monument, while reed canarygrass occurred on at least four acres. Of the 18 invasive exotic plants found in 2009, 10 taxa each occurred on less than one acre. Invasive plant species that were targeted with control showed greater relative decreases in frequency than species which that were not directly managed. Of the three species with minimal relative decreases in frequency - bluegrass, Canada thistle, and reed canarygrass – only Canada thistle was treated specifically. All six species that showed greater relative decreases in frequency were specifically targeted with control treatments. Six of the eight more abundant invasive species (minimum abundance>0.4 acres) decreased in frequency between 2006 and 2009, while almost equal numbers of the less abundant species increased or decreased in frequency. The cover of common buckthorn (*Rhamnus cathartica*), which park staff have treated aggressively, was reduced. In summary, these findings suggest that the park's control efforts have reduced the distribution and abundance of several invasive exotic plant species. This observation combined with the low abundance of many of the other species suggests that on-going park control efforts are likely to be very effective. The information presented in this report may be used to plan management activities leading to control of exotic plants and the accomplishment of GPRA goal IA1.

Introduction

An invasive exotic plant is a plant species that is not native to an area and is presumed to pose environmental harm to native plant populations or communities. In general, invasive exotic species fragment native ecosystems, displace native plants and animals, and alter ecosystem function. Invasive species are second only to habitat loss as threats to global biodiversity (Scott and Wilcove 1998). Prevention and early detection are the principal strategies for successful invasive exotic plant management. Invasive exotic plants often undergo a lag period between introduction and subsequent colonization of new areas. Managers can take advantage of monitoring efforts to detect invasive exotic species early and initiate control actions before populations become well established (Welch and Geissler 2007).

The native and restored tallgrass prairie and globally rare Sioux quartzite prairies at Pipestone National Monument are significant cultural and natural resources. A number of highly invasive exotics plants have established in Pipestone National Monument. These include common buckthorn (*Rhamnus cathartica)*, crownvetch (*Securigera varia*), leafy spurge (*Euphorbia esula*), reed canarygrass (*Phalaris arundinacea*), smooth brome (*Bromus inermis*), sweetclover (*Melilotus officinalis*), and Tatarian honeysuckle (*Lonicera tatarica*). To address this challenge, the monument operates an aggressive program to control invasive exotic plants using fire, restoration, herbicide, and mechanical methods, including mowing, felling, and hand-pulling. Fire management at Pipestone National Monument is timed to protect the endangered western prairie fringed orchid (*Platanthera praeclara*), while also controlling smooth brome in the native and restored prairies.

Methods

Watch lists

The invasive exotic plants on three watch lists were sought during monitoring (Table 1). Invasive exotic plants not known to occur on the park according NPSpecies (the national NPS database for plant occurrence registration) constitute the “Early Detection Watch List”. Invasive exotic plants known to occur on the park based on NPSpecies constitute the “Park-Established Watch List”. The “Park-based Watch List” includes invasive exotic plants selected by park managers or network staff which may not have been included on the other lists due to incomplete information in NPSpecies (e.g., not documented) or USDA Plants (e.g., state distribution information inaccurate) databases or due to differing opinions regarding network designation of a plant as a high priority. While aquatic species are included on the watch lists, terrestrial plants were the focus of this survey. Aquatic plants were documented only occasionally.

Field methods

Invasive exotic plant species on designated watch lists (Table 1) were sought in Pipestone National Monument (Figure 1) during July 6-7, 2006 and July 9-11, 2009. Craig Young, Tyler Cribbs, Karola Mlekush, and Brittany Hummel conducted the survey in 2006, while Craig Young,, Josh Brinkman, and Seth Hendriks conducted the survey in 2009. Josh Brinkman and Seth Hendriks were associated with Pipestone National Monument as biological technicians. Observers navigated along three transects through each search unit, identified invasive exotic plants in a 3 m- to 12 m-belt and attributed a coarse cover value to each species (0=0, 1=0.1-0.9

m^2, $2=1\text{-}9.9\ m^2$, $3=10\text{-}49.9\ m^2$, $4= 50\text{-}99.9\ m^2$, $5=100\text{-}499.9\ m^2$, $6= 499.9\text{-}999.9\ m^2$, and $7 \geq 1{,}000\ m^2$). Observers spaced themselves approximately equidistantly along the east or west border of a search unit prior to searching the unit in an easterly or westerly direction. Transects, however, were not marked, such that the exact position of each transect may have varied between years. The widest belt possible given site conditions was used. A total of 114 search units were surveyed (Figure 1). Unit size ranged between 0.8 – 4.1 acres with a mean size of 2.4 acres. A total of 30% of search units ranged between 0.8 and 1.9 acres, 57% ranged between 2.0 and 3.0 acres, and 13% were between 3.0 and 4.1 acres in size. Because of its earlier flowering date, Seth Hendriks conducted haphazard walk-throughs of the units known or expected to to contain dame's rocket (*Hesperis matronalis*) during May 28-29.

To facilitate ease of field identification between Kentucky and Canada bluegrass (*Poa pratensis* and *Poa compressa*, respectively), both species were categorized as *Poa* spp. and were analyzed as a single taxon. Similarly, we did not distinguish autumn olive (*Elaeagnus umbellata*) and Russian olive (*Elaeagnus angustifolia*), which we recorded as *Elaeagnus* spp. Finally, shrub honeysuckle plants surveyed were documented as *Lonicera* spp. During the survey, we recorded coralberry (*Symphoricarpos orbiculatus*) as bush honeysuckle, but were able to remove these entries from the dataset based on field notes. (We had suspected that our initial identification of coralberry might be incorrect and made notes accordingly.)

Analytical methods

Data analysis involved simple displays, as well as calculation of plant cover and frequency. The invasive exotic plants encountered on Herbert Hoover National Historic Site were attributed to search units in a GIS (Figures 2 – 28). Note that entire search units were not fully searched. A park-wide cover range was estimated for each invasive exotic plant encountered.

We calculated the observed reference frame fraction by multiplying transect length, the number of transects, and the belt width. The belt width was either 3 m (the minimum possible width) or 12 m (the maximum possible width). The product was then divided by the reference frame area (Eq. 1). We calculated transect lengths using the mean sample unit size and assuming square search units.

$$\text{Eq. 1. Fraction of area searched} = \frac{\textit{transect length * number of transects * belt width}}{\textit{reference frame area}}$$

The minimum fraction of area searched (belt width = 3 m) was 0.092, and the maximum fraction of area searched (belt width = 12 m) was 0.368.

To calculate the minimum end of the estimated cover range for each species, we summed the lower endpoints associated with the assigned cover class values for that species and then divided by the reference frame fraction observed assuming the widest possible survey belt (i.e., maximum fraction observed) (12 m) (Eq. 2).

$$\text{Eq. 2. Minimum cover estimate} = \frac{\Sigma\ \textit{low end of cover value range for species}}{\textit{fraction of area searched assuming 12-m belt width}}$$

Maximum cover for each species was calculated similarly, using the upper endpoints of the cover values in each occupied search unit and assuming that a 3 m belt was surveyed (i.e., minimum fraction of area observed) (Eq. 3).

$$\text{Eq. 3. Maximum cover estimate} = \frac{\underline{\Sigma\ \textit{high end of cover value range for species}}}{\textit{fraction of area searched assuming 3-m belt width}}$$

Taken together, the minimum and maximum cover estimates provide an estimated range of cover that accounts for the uncertainty arising from the sampling method. Non-overlapping ranges represent the strongest evidence for differences in abundance.

The park-wide frequency of invasive exotic plants was calculated as the percentage of occupied search units (Eq. 4).

$$\text{Eq. 4. Frequency of an IEP species} = \frac{\underline{\Sigma\ \textit{units occupied by species}}}{\Sigma\ \textit{units sampled}} \text{ X100}$$

Invasiveness ranks

In order to provide additional information on the ecological impact and feasibility of control, the ecological impact and general management difficulty sub-ranks that constitute the invasiveness rank (I-rank), as determined by NatureServe (Morse et al. 2004), were listed when available. The ecological impact characterizes the effect of the plant on ecosystem processes, community composition and structure, native plant and animal populations, and the conservation significance of threatened biodiversity. General management difficulty ranks are assigned based on the resources and time generally required to control a plant, the non-target effects of control on native populations, and the accessibility of invaded sites. Sub-ranks are given as high (H), medium (M), low (L), insignificant (I), unknown (U), or a combination of ranks.

Results and Discussion

A cumulative total of 20 invasive exotic plant taxa were found during surveys at Pipestone National Monument in 2006 and 2009 (Table 2). The majority of the invasive exotic plant species identified during the survey were already known to occur at Pipestone National Monument due to the park's strong botanical record. We did not find any plants on the early detection list and documented only one species on the park-based list.

The distribution and abundance of invasive exotic plant species at Pipestone National Monument varied widely. Three invasive perennial cool-season grasses were widespread and abundant: smooth brome, bluegrass, and reed canarygrass. The estimated cover of smooth brome exceeded 31 acres, occurring at a frequency of 99.1 % in 2009. Bluegrass covered a minimum of 21 acres and had a high frequency of 98.2%. The third most prominent invasive grass in the monument, reed canarygrass, covered at least 6.5 acres and occupied 47.4% of park search units. Only five other invasive exotic plants displayed park-wide cover in excess of at least 0.5 acres: Canada thistle (*Cirsium arvense*), common buckthorn, crownvetch, shrub honeysuckle, and sweetclover. As observed in 2006, the road to the east of the park appeared to serve as a conduit for crownvetch invasion.

Comparisons of invasive plant abundance and frequency between 2006 and 2009 required careful consideration of the uncertainty associated with the measurements outlined in the monitoring protocol (Young et al 2007). We recognized two sources of uncertainty when analyzing occurrence (i.e., frequency) patterns within or between years. First, observers can make mistakes in their observations such as overlooking or misidentifying plants within transects. The use of trained botanists and technicians is intended to minimize this source of uncertainty. Second, because transect locations and widths may vary between years, differences in plant detection may reflect natural spatial variability. This factor may strongly affect plant detection rates in any single search unit, but should vary randomly across all units. Such sampling error, which should be mitigated through the approximately similar location of transects between years, poses the greatest challenge to data interpretation in this protocol. While we observed a high portion of the reference frame compared to traditional sampling approaches (Young and Haack 2009), observers cannot observe all areas of the park. Additional observations from park staff or citizen scientists would increase detection of invasive plant species.

Given these sources of error, three possible scenarios could characterize changes in the frequency of invasive plant species between 2006 and 2009: In the first scenario, a species found within a search unit during the first and second sampling periods confirmed the longevity of the species in that location. In the second scenario, in which a species was not found in a search unit during either sampling period, we assumed that the species was absent or at least not highly abundant or widely distributed as these characteristics would increase detection probabilities. The third scenario–when a species found in a search unit during one sampling period and not during the next–was the most problematic. This observation could reflect species turnover or a dramatic fluctuation in abundance that is typically associated with annual species. Alternatively, a species may have been present but not recorded either due to observer mistakes (, which we expect are minimal), or to sampling error arising from the use of non-permanent transects and variable belt widths along transects.

The assumption made here for the third scenario will not always be appropriate. For example, a species that is not found or found at low frequency during an early sampling period and is then found in a relatively large number of search units during a later sampling period may be actively invading. Alternatively, for species subject to control actions, decreases in frequency between or among surveys could result from such management. Relatively dramatic changes in frequency, however, will only be expected for species with low abundance that respond readily to management techniques. In either case, such patterns will be best documented by increasing or decreasing trends from several years of survey data, and it is difficult in most cases to make definitive conclusions from only two years of data. For this report, frequencies are analyzed based on the data as collected, although in many cases species recorded in only one time period may have been present during both sampling periods. Thus, if it is desirable to control select species, we advise managers to visit all search units where the species occurred in either 2006 or 2009.

Eight of the 20 invasive plant species increased in frequency between 2006 and 2009. The increase was slight for crownvetch, nodding plumeless thistle, and smooth brome, which were all largely common in 2006 and occurred in at least 18% of the search units. Crownvetch was treated in 2008 with Transline, while thistles were pulled by hand annually between 2005 and

2009. We observed relatively large increases on a relative basis for three species that were uncommon (occurring in < 10% of the search units) in 2006: autumn./Russian olive, dame's rocket, and field sowthistle (*Sonchus arvensis*). Park staff control the former two species with cutting and hand-pulling, respectively. Sowthistle was not treated. Two species, bald brome and leafy spurge, were not documented in 2006. Given that bald brome was so widespread (25.4% frequency) in 2009 compared to 2006, observers most likely overlooked this species in 2006. Based on the medium to insignificant impact of the plant, control efforts are not warranted. Park staff treat leafy spurge annually using Plateau.

Invasive plant species that were established on the park in 2006 and that were targeted with control actions showed greater relative decreases in frequency than species that were only managed with fire. Of the three species with minimal relative decreases in frequency (<10%) – bluegrass, Canada thistle, and, reed canarygrass – only Canada thistle was treated specifically. All six species that showed greater relative decreases in frequency, were specifically controlled. For example, bull thistle, common mullein, and sweetclover, all hand-pulled annually, showed relative decreases in frequency of 16%, 32%, and 37%, respectively. Bush honeysuckle, common buckthorn, and Siberian elm, which were cut and stump-treated with herbicide, had relative decreases in frequency of 12.8%, 54.4%, and 79.5%, respectively. Butter-and-eggs (*Linaria vulgaris*), which was not hand-pulled, was the only species that did not change in frequency between 2006 and 2009.

We examined the entire suite of invasive exotic plant species to assess general changes in frequency between 2006 and 2009. Given that sampling error between years should be random (i.e., expected value for increasing and decreasing categories = 50%), we found that six of the eight species (75%) with minimum abundance $\geq$ 0.4 acres in 2009 decreased in frequency. Of the 12 species with minimum cover < 0.4 acres, the frequency decreased for five species (42%), increased for six species (50%), and remained unchanged for one species (8%). This observation suggests that there is not a clear trend increasing or decreasing trend in frequency across species.

Interpreting changes in the abundance of invasive plant species between 2006 and 2009 required considerations of uncertainty in addition to those made for frequency. For example, in addition to observer detection mistakes, abundance estimates include error resulting from incorrect assignment of cover classes. As with detection, abundance estimation may vary between years due to variability in transect location, although the approximate similarity in location between years should mitigate this error. The uncertainty resulting from measurement error (i.e., the use of cover class ranges rather than point estimates) and the uncertainty resulting from variable belt widths are accounted for in the cover range provided for each invasive plant species (see *Analytical Methods*). For the purposes of comparing cover ranges for each species between 2009 and 2006, non-overlapping cover ranges represent the strongest evidence for a change in the abundance of a species between 2006 and 2009. Cover ranges may be very broad, however, and increase with abundance. Thus, relatively large differences in overlapping cover ranges could also be informative. For such overlapping cover ranges, the degree of overlap should be proportional to the strength of evidence for a true difference in abundance. Consequently, a high degree of overlap in range represents a lower probability of a difference than a low degree of overlap.

Based on non-overlapping cover ranges, we identified only field sowthistle as changing in abundance between 2006 and 2009. However, we observed this species at very low abundance during both years. Although cover ranges for common buckthorn overlapped, the seven-fold decrease in maximum abundance presumably represented a decrease between 2006 and 2009. This finding suggests that the cut stump treatment has substantially decreased buckthorn cover throughout the park. One counter-intuitive finding was that sweetclover cover may have increased despite a dramatic reduction in frequency. Based on the map (Figure 12), central portions of the park appear to now be free of sweetclover and cover in the eastern portion of the park has been reduced, while an increase in cover on the western side of the park may have offset some of these gains. With the exception of buckthorn, we interpreted the rest of the overlapping ranges as reflecting general similarity in abundance between 2006 and 2009. Viewing the entire suite of invasive species with abundance greater than 0 during 2006 and 2009 as a whole (n=16), the maximum cover estimate increased for 62.5% of species and decreased for 37.5% of species. (The use of inequalties in Table 2 obscures this difference in two species.)

Three species were noted as having unambiguously high ecological impact: crownvetch, reed canarygrass, and Russian/autumn olive (Table 2). A medium ecological impact characterized five of the surveyed species. The remaining species have ambiguous medium-low ecological impacts or less with a low or insignificant impact. Recognizing that the feasibility of control often strongly influences decisions regarding invasive exotic plant management, crownvetch and autumn olive with high ecological impacts were noted as having low management difficulty. Additionally, many invasive exotic species occur on less than half of an acre. Controlling these species will likely provide a relatively high benefit for the cost.

Literature Cited

Morse, L. E., J. M. Randall, N. Benton, R. D. Hiebert, and S. Lu. 2004. An Invasive Species Assessment Protocol: Evaluating Non-Native Plants for Their Impact on Biodiversity. Version 1. Document. Online. (http://www.natureserve.org/getData/plantData.jsp#InvasivesProtocol). Accessed 1 December 2006.

Scott, J. M. and D. S. Wilcove. 1998. Improving the future for endangered species. Bioscience 48(8): 579-80.

Welch, B.A. and P.H. Geissler. 2007. Early detection of invasive plants: a handbook. United States Geological Survey draft. Online. (http://www.pwrc.usgs.gov/brd/invasiveHandbook.cfm). Accessed 1 February 2010.

Williamson B. and A. Fitter. 1996. The varying success of invaders. Ecology 77:1661–1666.

Young, C. C., J. L. Haack, L. W. Morrison, and M. D. DeBacker. 2007. Invasive Exotic Plant Monitoring Protocol for the Heartland Network Inventory and Monitoring Program. Natural Resource Report NPS/HTLN/NRR-2007/018. National Park Service, Fort Collins, Colorado.

Young C. C. and J. L. Haack. 2009. A rapid, invasive plant survey method for national park units with a cultural resource focus. Park Science 26:70-75.

Apppendix
Figures and Tables

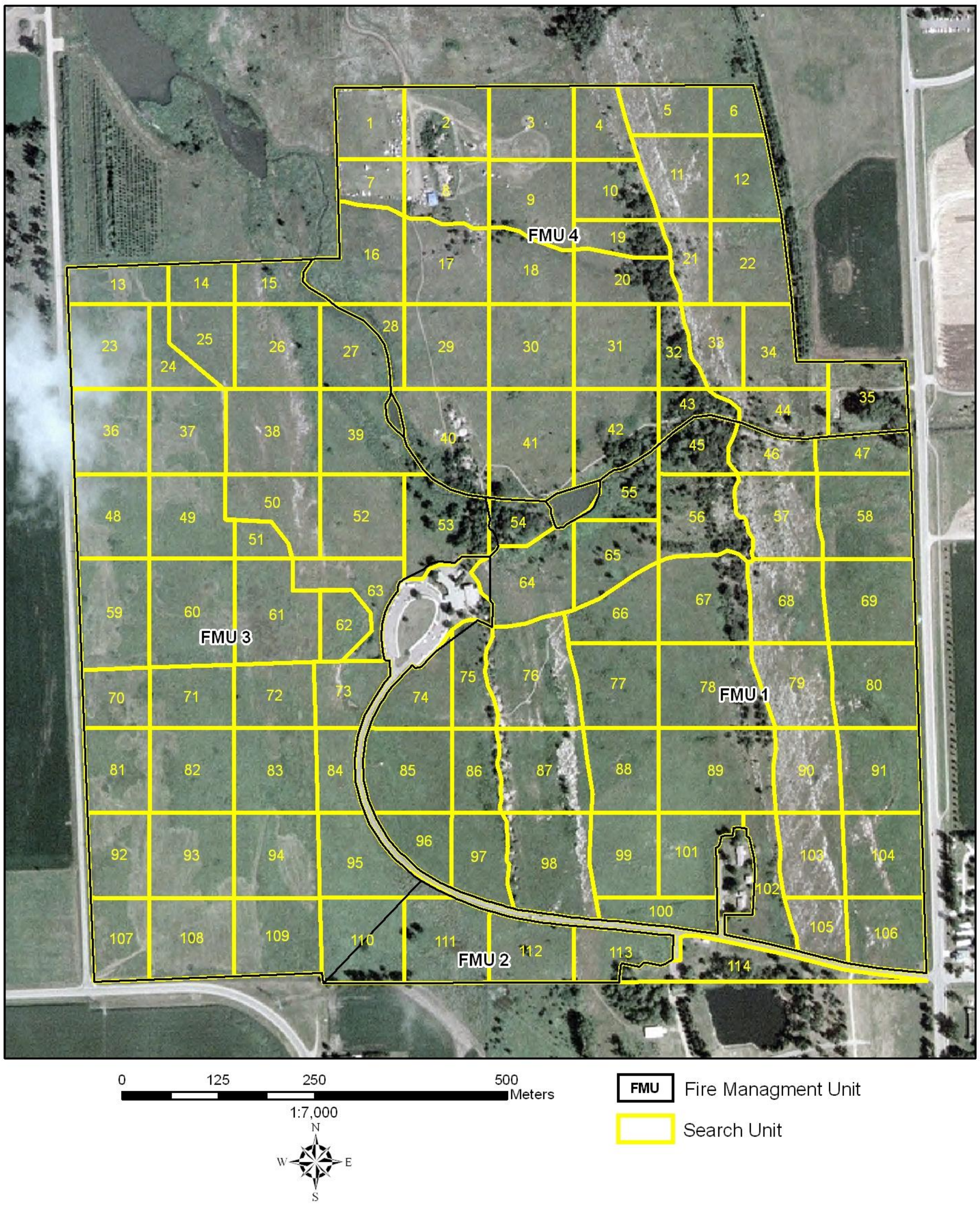

Figure 1. Invasive exotic plant search units at Pipestone National Monument. The search units indicate the search locations for invasive exotic plants in 2006 and 2009.

Table 1. Invasive exotic plant watch lists for Pipestone National Monument. The symbol ^ denotes aquatic plant species.

Early Detection Watch List		Park-Established Watch List		Park-Based Watch List	
Acer ginnala	Amur maple	*Arctium minus*	Lesser burdock	*Bromus racemosus*	Bald brome
Acer platanoides	Norway maple	*Bromus inermis*	Smooth brome	*Elymus repens*	Quackgrass
Alliaria petiolata	Garlic mustard	*Bromus tectorum*	Cheatgrass	*Leucanthemum vulgare*	Oxeye daisy
Alnus glutinosa	European alder	*Carduus nutans*	Nodding plumeless thistle	*Lolium perenne*	Perennial ryegrass
Azolla^	Mosquitofern	*Cirsium arvense*	Canada thistle	*Phleum pratense*	Timothy
Berberis thunbergii	Japanese barberry	*Cirsium vulgare*	Bull thistle		
Berteroa incana	Hoary alyssum	*Elaeagnus angustifolia*	Russian olive		
Butomus umbellatus	Flowering rush	*Euphorbia esula*	Leafy spurge		
Caragana arborescens	Siberian peashrub	*Hesperis matronalis*	Dames rocket		
Centaurea biebersteinii	Spotted knapweed	*Linaria vulgaris*	Butter and eggs		
Centaurea solstitialis	Yellow star-thistle	*Lonicera tatarica*	Tatarian honeysuckle		
Cynanchum louiseae	Louise's swallow-wort	*Melilotus officinalis*	Yellow sweetclover		
Dactylis glomerata	Orchardgrass	*Phalaris arundinacea*	Reed canarygrass		
Daucus carota	Queen Anne's lace	*Poa compressa*	Canada bluegrass		
Digitalis lanata	Grecian foxglove	*Poa pratensis*	Kentucky bluegrass		
Dipsacus laciniatus	Cutleaf teasel	*Potentilla recta*	Sulphur cinquefoil		
Frangula alnus	Glossy buckthorn	*Rhamnus cathartica*	Common buckthorn		
Glechoma hederacea	Ground ivy	*Securigera varia*	Crownvetch		
Hieracium aurantiacum	Orange hawkweed	*Solanum dulcamara*	Climbing nightshade		
Humulus japonicus	Japanese hop	*Sonchus arvensis*	Field sowthistle		
Iris pseudacorus^	Paleyellow iris	*Ulmus pumila*	Siberian elm		
Leucanthemum vulgare	Oxeye daisy	*Verbascum thapsus*	Common mullein		
Lolium arundinaceum	Tall fescue				
Lolium pratense	Meadow fescue				
Lonicera maackii	Amur honeysuckle				
Lonicera morrowii	Morrow's honeysuckle				
Lonicera X bella	Showy fly honeysuckle				
Lotus corniculatus	Bird's-foot trefoil				
Lotus tenuis	Narrow-leaf bird's-foot trefoil				

Table 1 (cont.). Invasive exotic plant watch lists for Pipestone National Monument.

Early Detection Watch List		Park-Established Watch List		Park-Based Watch List	
Lysimachia nummularia	Creeping jenny				
Lythrum salicaria	Purple loosestrife				
Miscanthus saccharifolius	Amur silvergrass				
Morus alba	White mulberry				
Myriophyllum spicatum^	Eurasian watermilfoil				
Pastinaca sativa	Wild parsnip				
Phragmites australis	Common reed				
Plantago lanceolata	Narrowleaf plantain				
Polygonum cuspidatum	Japanese knotweed				
Polygonum sachalinense	Giant knotweed				
Populus alba	White poplar				
Potamogeton crispus	Curly pondweed				
Robinia pseudoacacia	Black locust				
Rosa multiflora	Multiflora rose				
Tanacetum vulgare	Common tansy				
Typha angustifolia	Narrowleaf cattail				
Viburnum opulus	European cranberrybush				
Vicia cracca	Bird vetch				
Vicia villosa	Winter vetch				
Vinca minor	Common periwinkle				

Table 2. Overview of invasive exotic plants found on Pipestone National Monument in 2006 and 2009. Inequalities rather than cover ranges are shown for species with maximum cover value less than 1 acre. Ecological impact and general management difficulty based on NatureServe I-Rank subranks, Morse et al. 2004. Subranks are given as high (H), medium (M), low (L), insignificant (I), unknown (U), a range of ranks (indicated by /), or not available (---).

Scientific Name	Common Name	Watch list	2006 Park-wide cover (acres)	2009 Park-wide cover (acres)	2006 Frequency (percent)	2009 Frequency (Percent) (Frequency difference 2006-2009)	Ecological impact	Management difficulty
Poa spp.	Kentucky / Canada bluegrass	Park-established	28.9 - 530.8	21.9 - 360.9	99.1	98.2 (-0.9)	M / ML	ML / HM
Bromus inermis	Smooth brome	Park-established	24.3 - 401.8	31.6 - 501.5	95.6	99.1 (3.5)	M	ML
Phalaris arundinacea	Reed canarygrass	Park-established	4.2 - 58.1	6.5 - 107.4	50.9	47.4 (-3.5)	H	HM
Rhamnus cathartica	Common buckthorn	Park-established	3.5 - 42.5	0.4 - 7.9	59.6	27.2 (-32.4)	M	M
Melilotus officinalis	Yellow sweetclover	Park-established	1.7 - 27.8	3.3 - 44.0	70.2	43.9 (-26.3)	M	M
Securigera varia	Crown vetch	Park-established	0.8 - 10.9	1.3 - 17.4	18.4	19.3 (0.9)	H	L
Cirsium arvense	Canada thistle	Park-established	0.4 - 6.1	0.5 - 8.3	63.2	62.3 (-0.9)	ML	HM
Lonicera spp.	Honeysuckle shrub	Park-established	0.3 - 3.9	0.4 - 5.7	21.1	18.4 (-2.7)	----	----
Elaeagnus spp.	Autumn / Russian olive	Park-established	< 0.75	< 0.5	3.5	1.8 (1.7)	H / HM	L / H
Carduus nutans	Nodding plumeless thistle	Park-established	< 0.5	< 0.5	30.7	32.5 (1.8)	MI	HM
Cirsium vulgare	Bull thistle	Park-established	< 0.5	< 0.25	21.9	18.4 (-3.5)	ML	ML
Verbascum thapsus	Common mullein	Park-established	< 0.5	< 0.25	19.3	13.2 (-6.1)	ML	L
Ulmus pumila	Siberian elm	Park-established	< 0.25	< 0.5	4.4	0.9 (-3.5)	ML	ML
Hesperis matronalis	Dames rocket	Park-established	< 0.1	< 0.1	9.6	14 (4.4)	MI	HL
Phleum pratense	Timothy	Park-based	< 0.1	0	0.9	0 (-0.9)		
Linaria vulgaris	Butter and eggs	Park-established	< 0.01	< 0.1	3.5	3.5 (0)	ML	HM
Sonchus arvensis	Field sowthistle	Park-established	< 0.01*	< 0.25*	0.9	4.4 (3.5)	LI	HL
Solanum dulcamara	Climbing nightshade	Park-established	< 0.01	0	0.9	0 (-0.9)	L	LI
Bromus racemosus	Bald brome	Park-based	0	0.2 - 2.4	0	25.4 (25.4)	MI	MI
Euphorbia esula	Leafy spurge	Park-established	0	< 0.25	0	3.5 (3.5)	M	H

*True difference in cover assumed based on non-overlapping cover ranges.

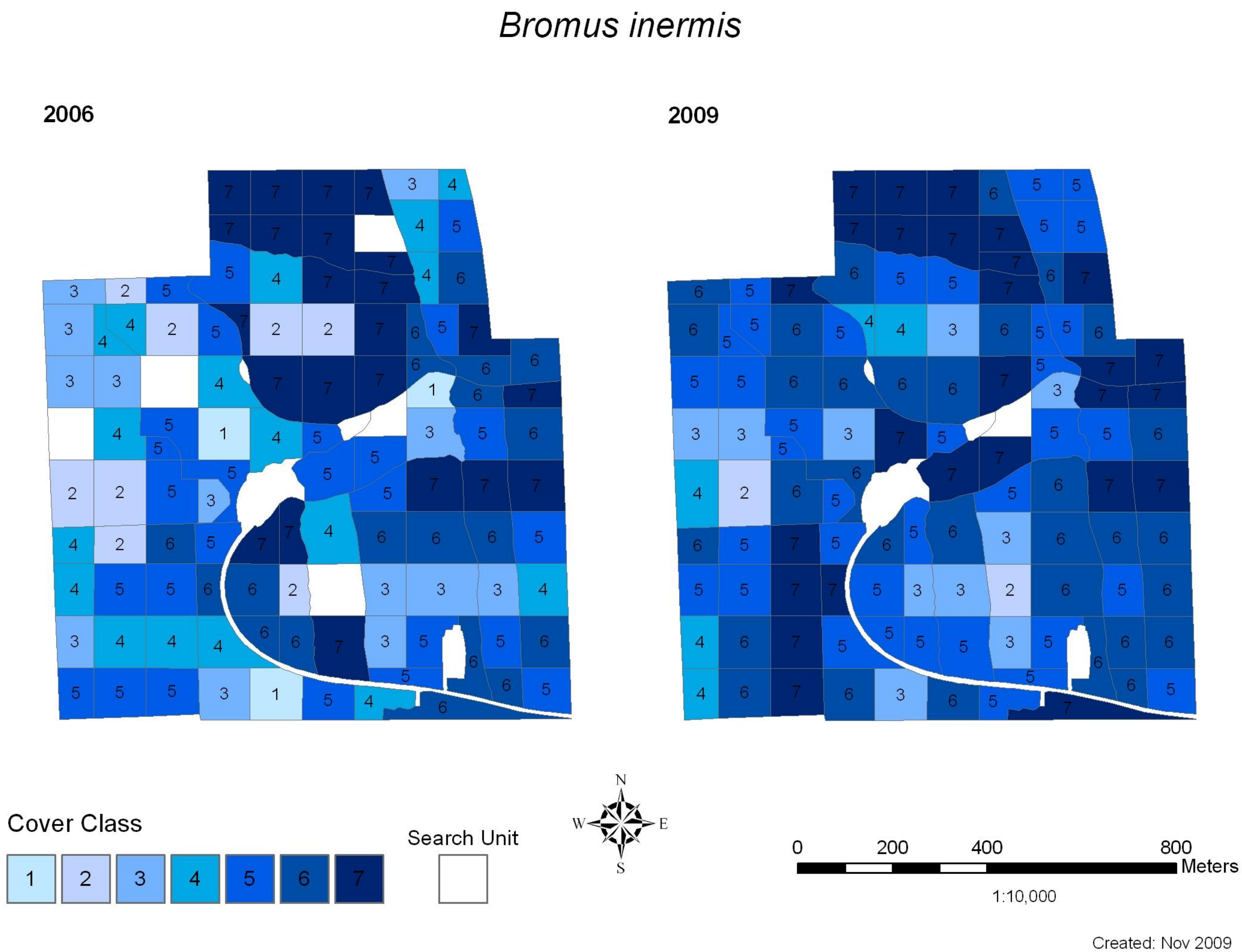

Figure 2. Abundance and distribution of *Bromus inermis* (smooth brome) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m², 2=1-9.9 m², 3=10-49.9 m², 4= 50-99.9 m², 5=100-499.9 m², 6= 499.9-999.9 m², and 7 ≥ 1,000 m².

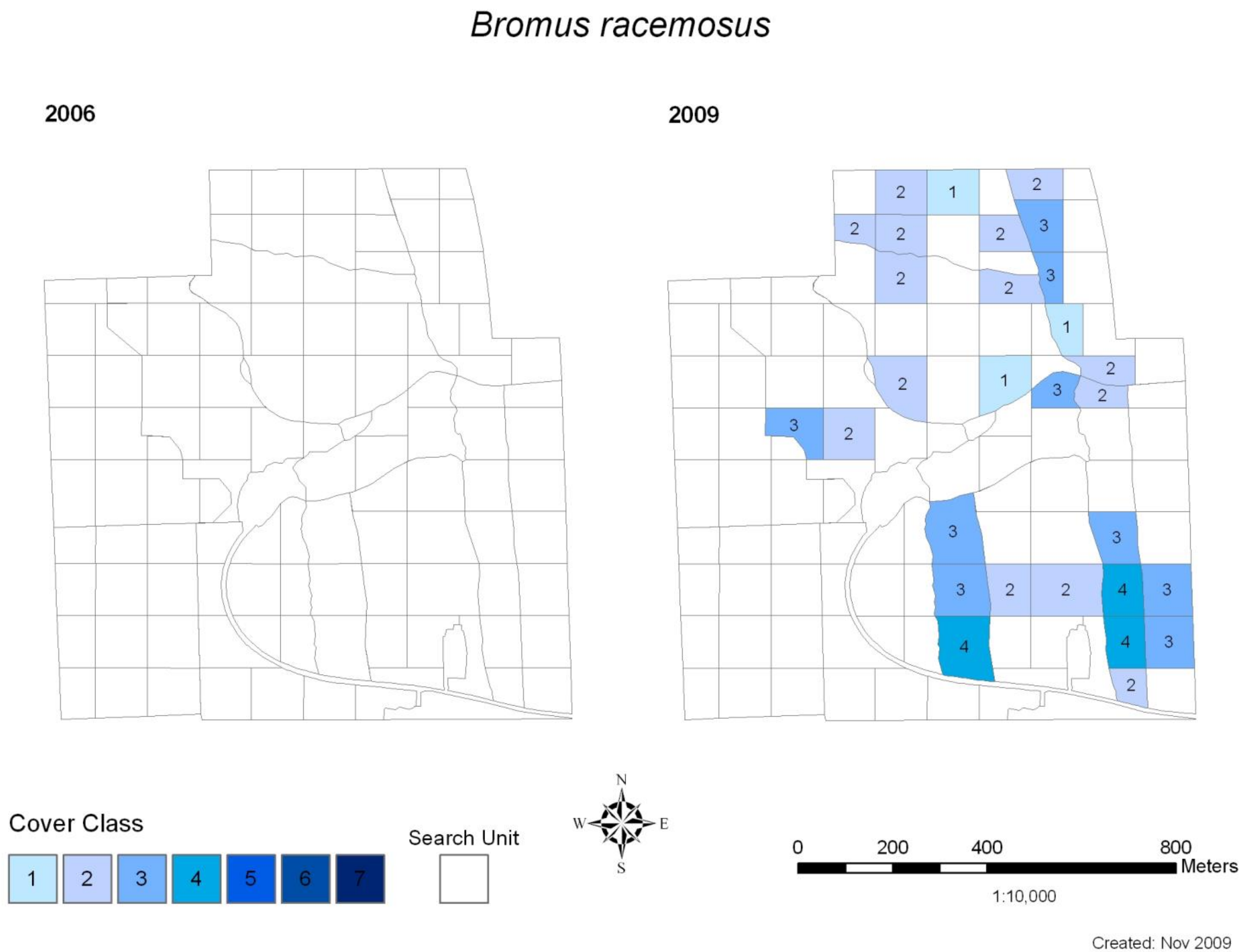

Figure 3. Abundance and distribution of *Bromus racemosus* (bald brome) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m².

Carduus nutans

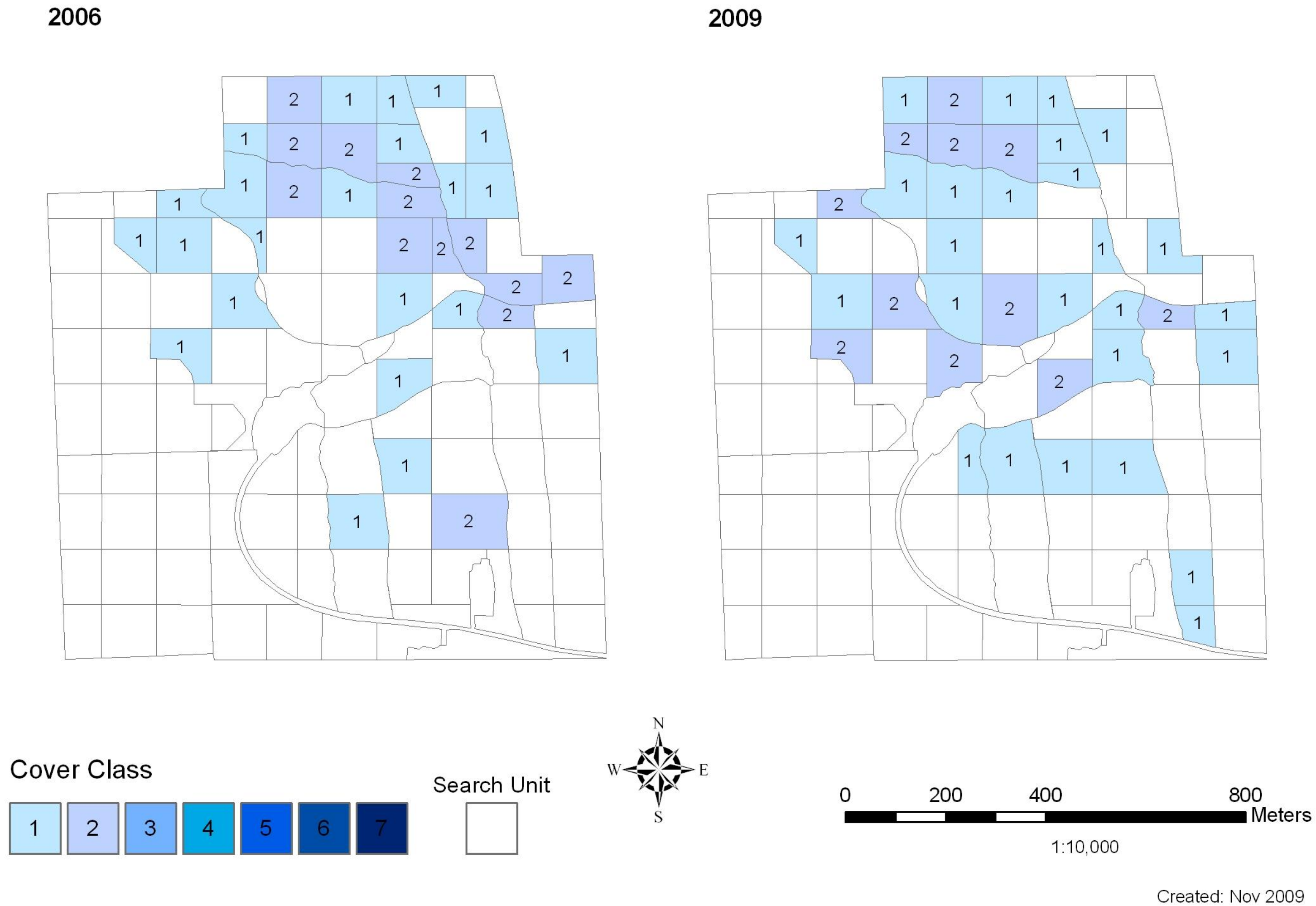

Figure 4. Abundance and distribution of *Carduus nutans* (nodding plumeless thistle) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m^2.

Cirsium arvense

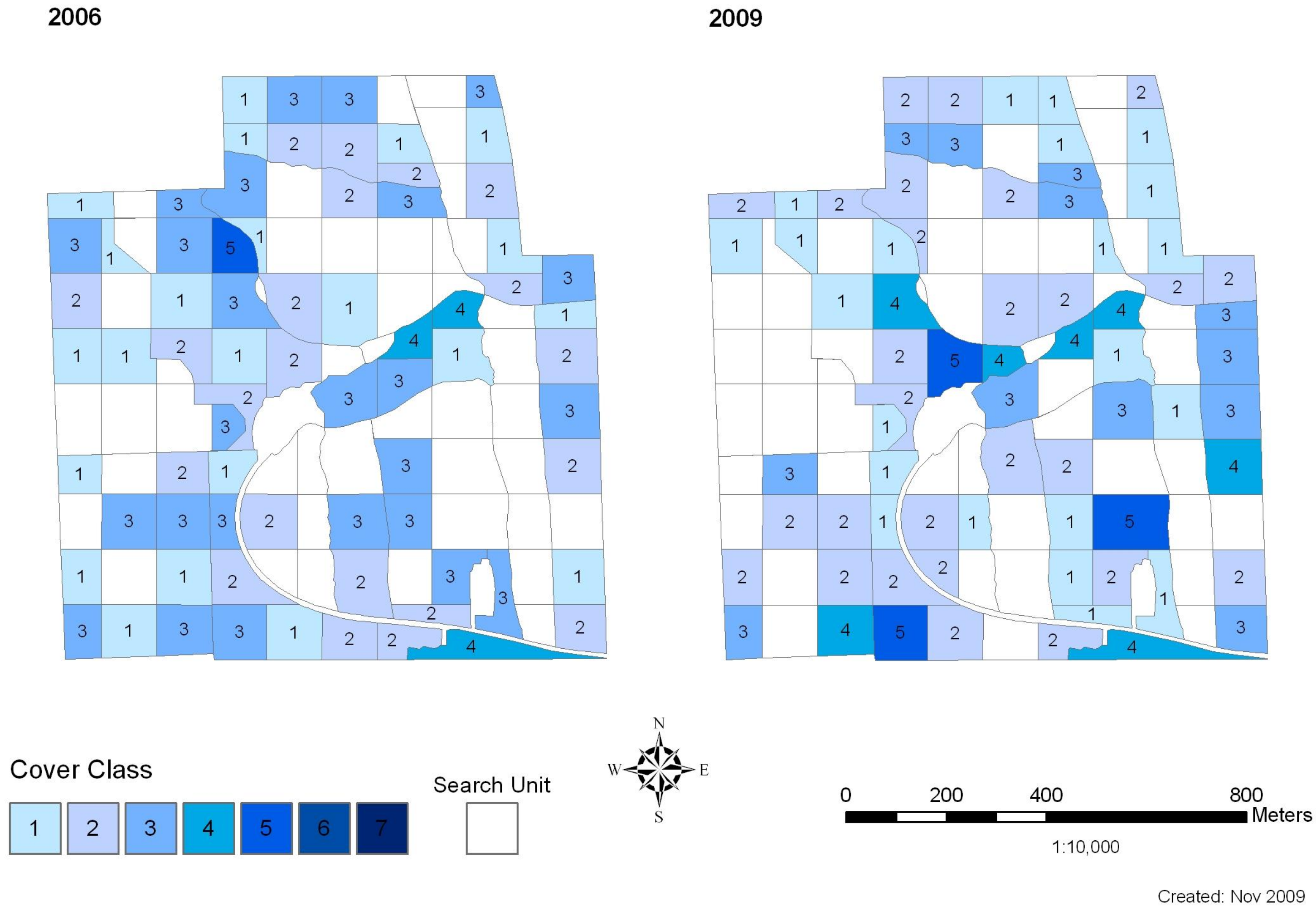

Figure 5. Abundance and distribution of *Cirsium arvense* (Canada thistle) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m².

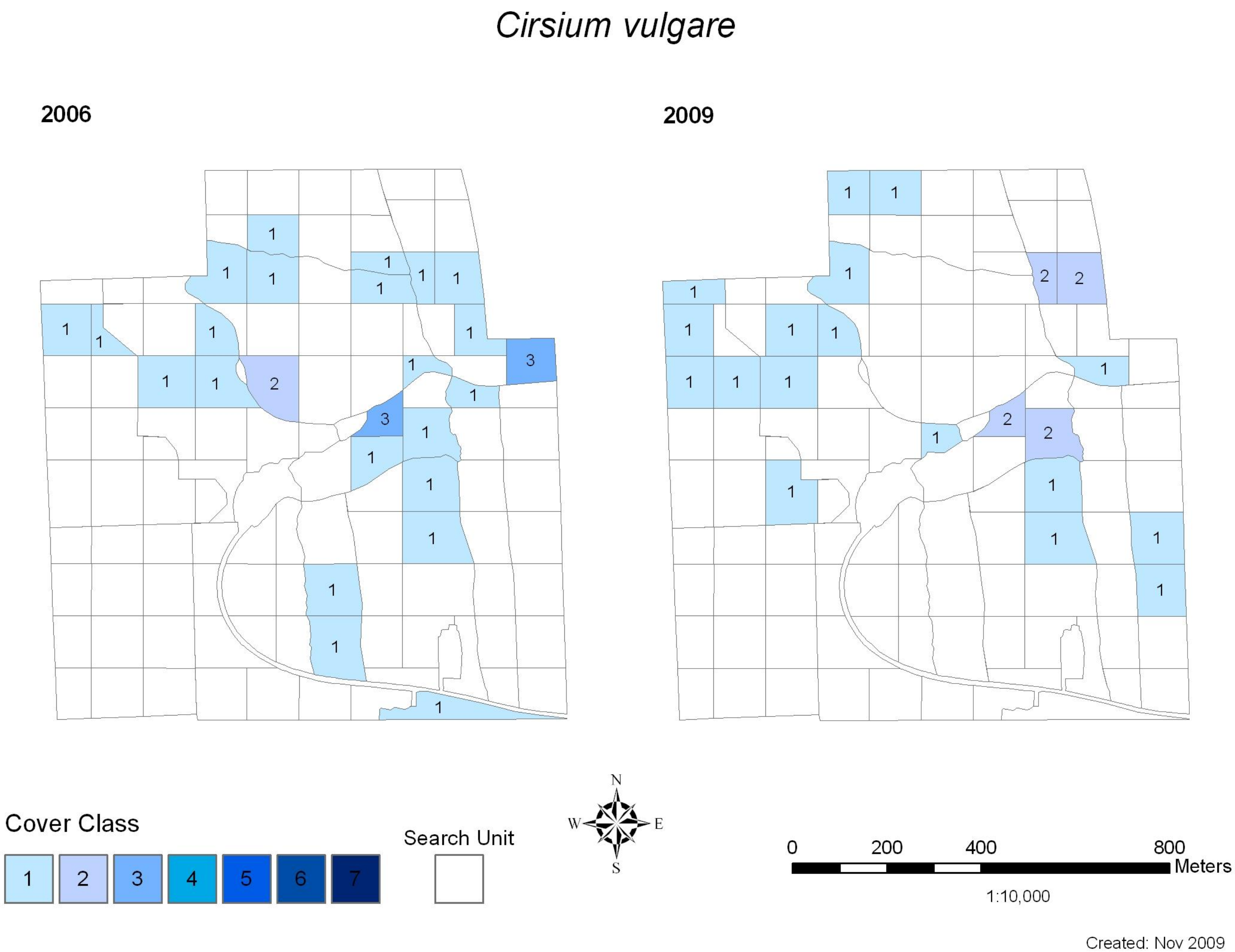

Figure 6. Abundance and distribution of *Cirsium vulgare* (bull thistle) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m².

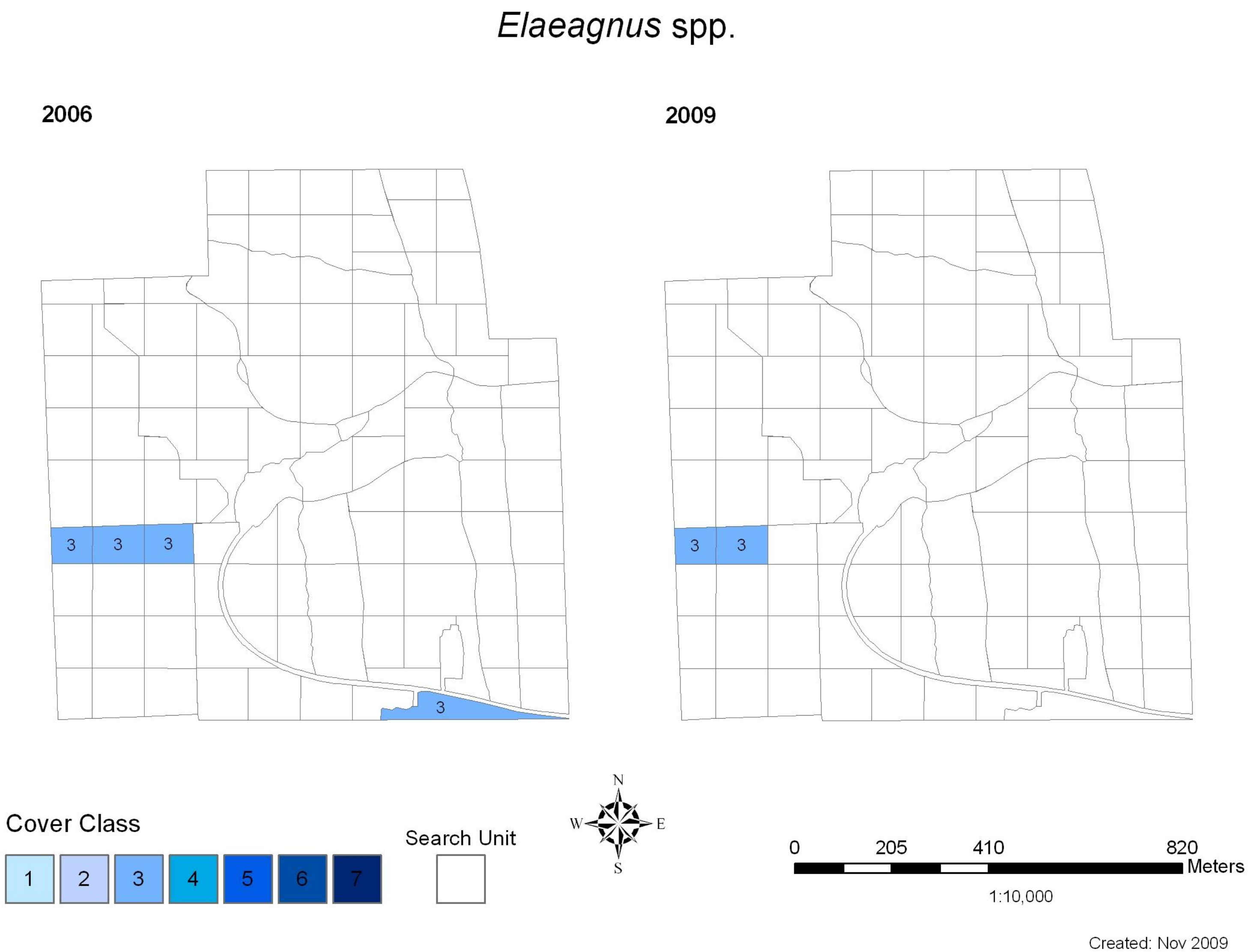

Figure 7. Abundance and distribution of *Elaeagnus* spp. (autumn / Russian olive) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m^2

Euphorbia esula

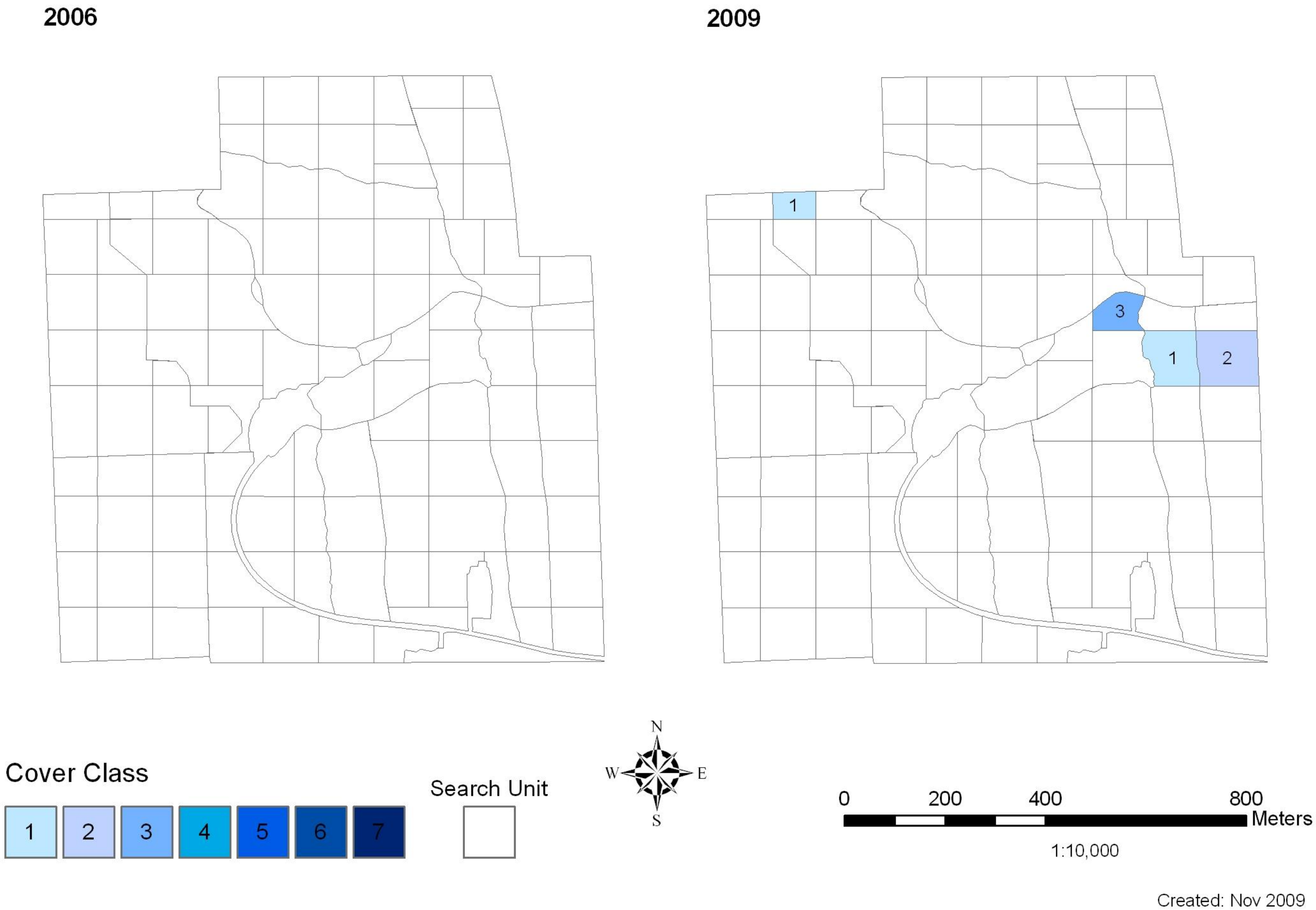

Figure 8. Abundance and distribution of *Euphorbia esula* (leafy spurge) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m^2.

Hesperis matronalis

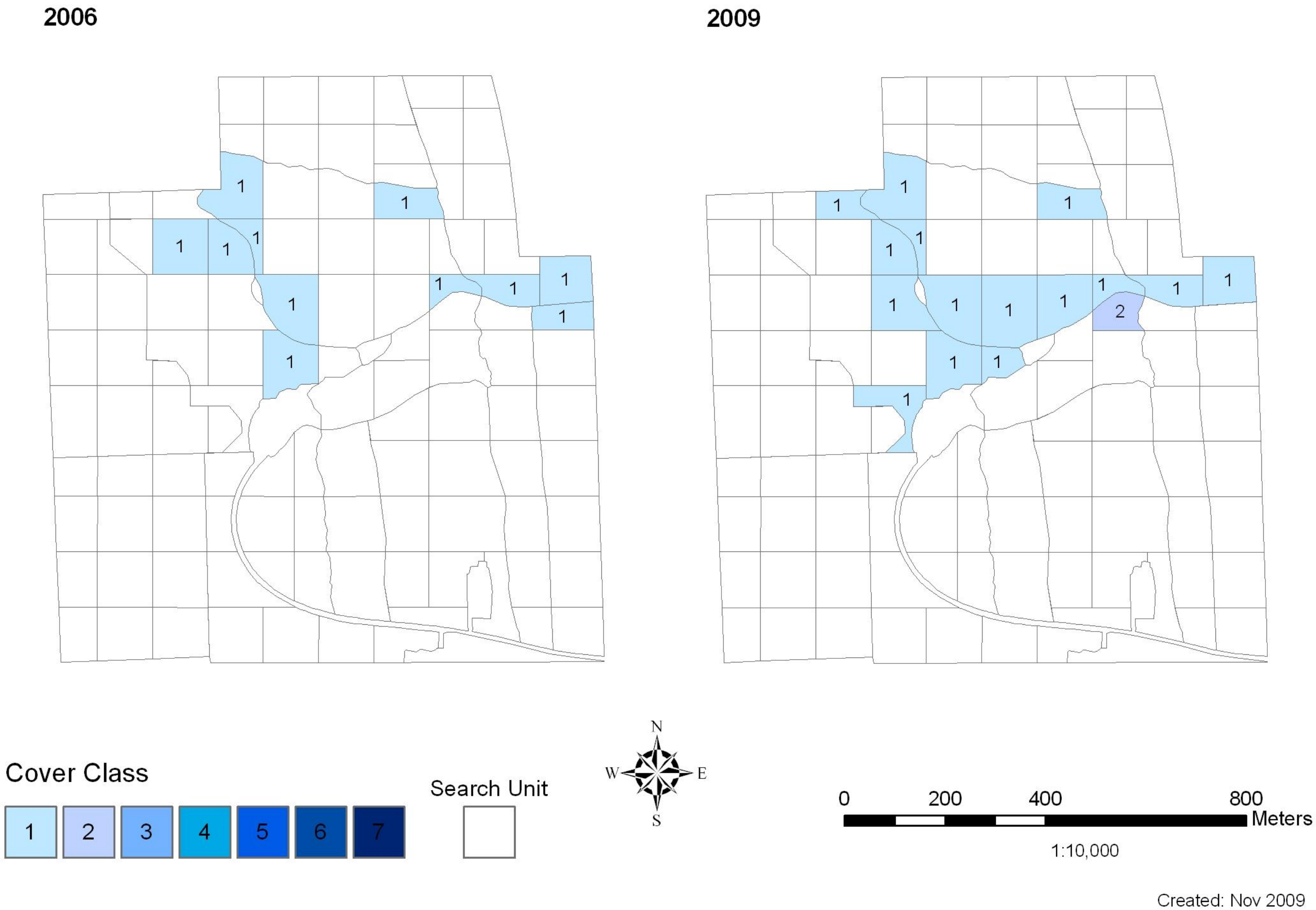

Figure 9. Abundance and distribution of *Hesperis matronalis* (dames rocket) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m^2.

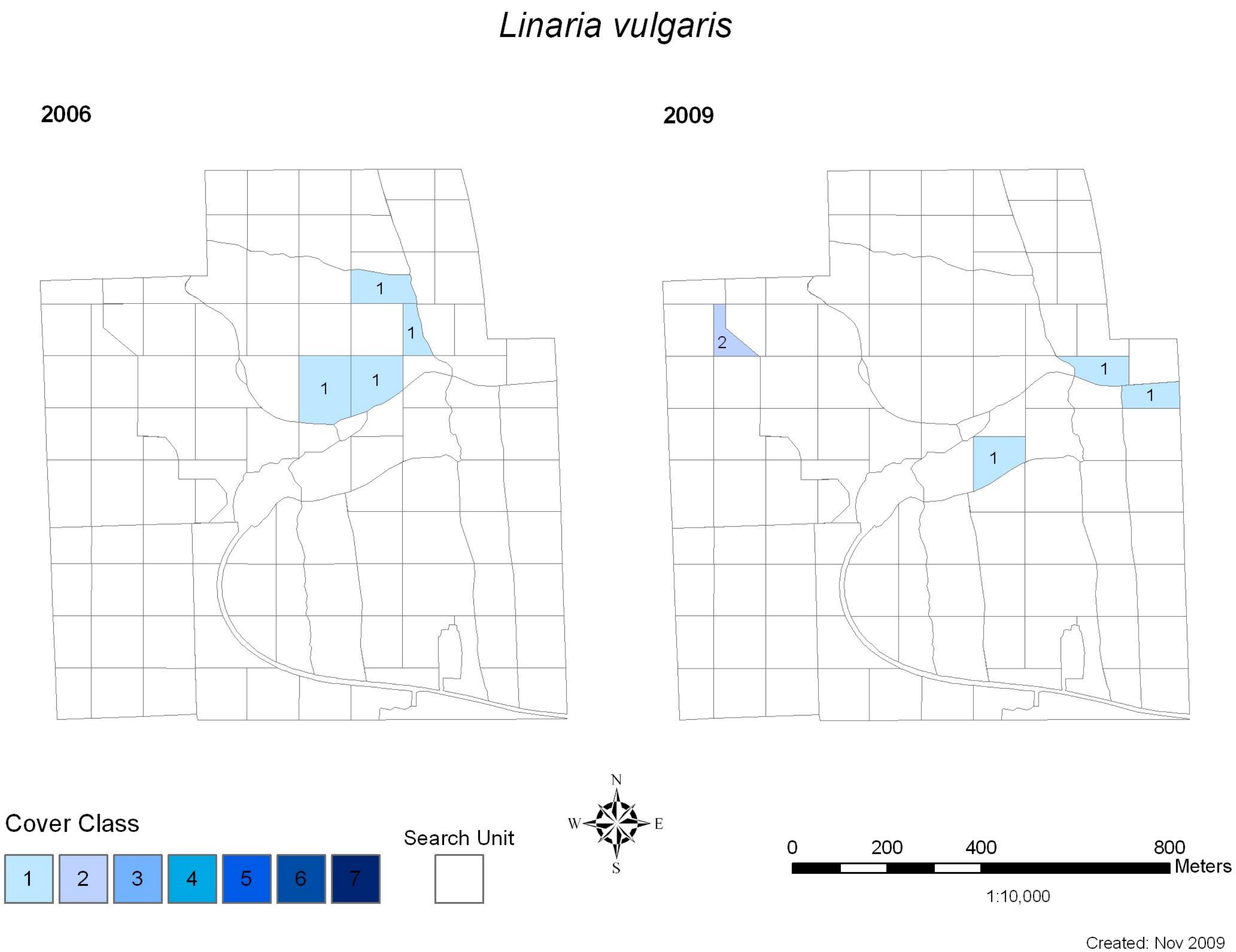

Figure 10. Abundance and distribution of *Linaria vulgaris* (butter and eggs) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m^2.

Lonicera spp.

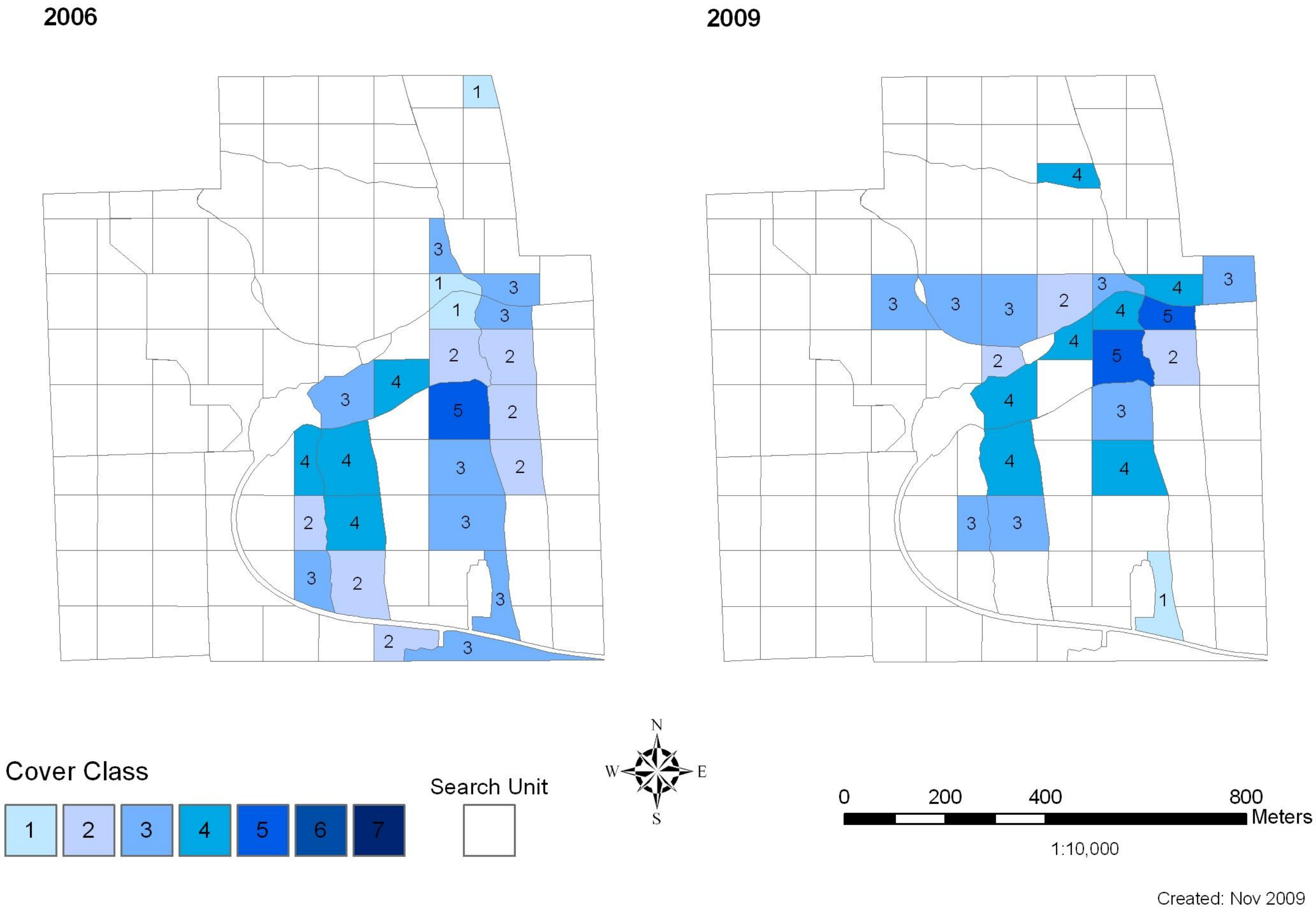

Figure 11. Abundance and distribution of *Lonicera* spp. (honeysuckle shrub) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m².

Melilotus officinalis

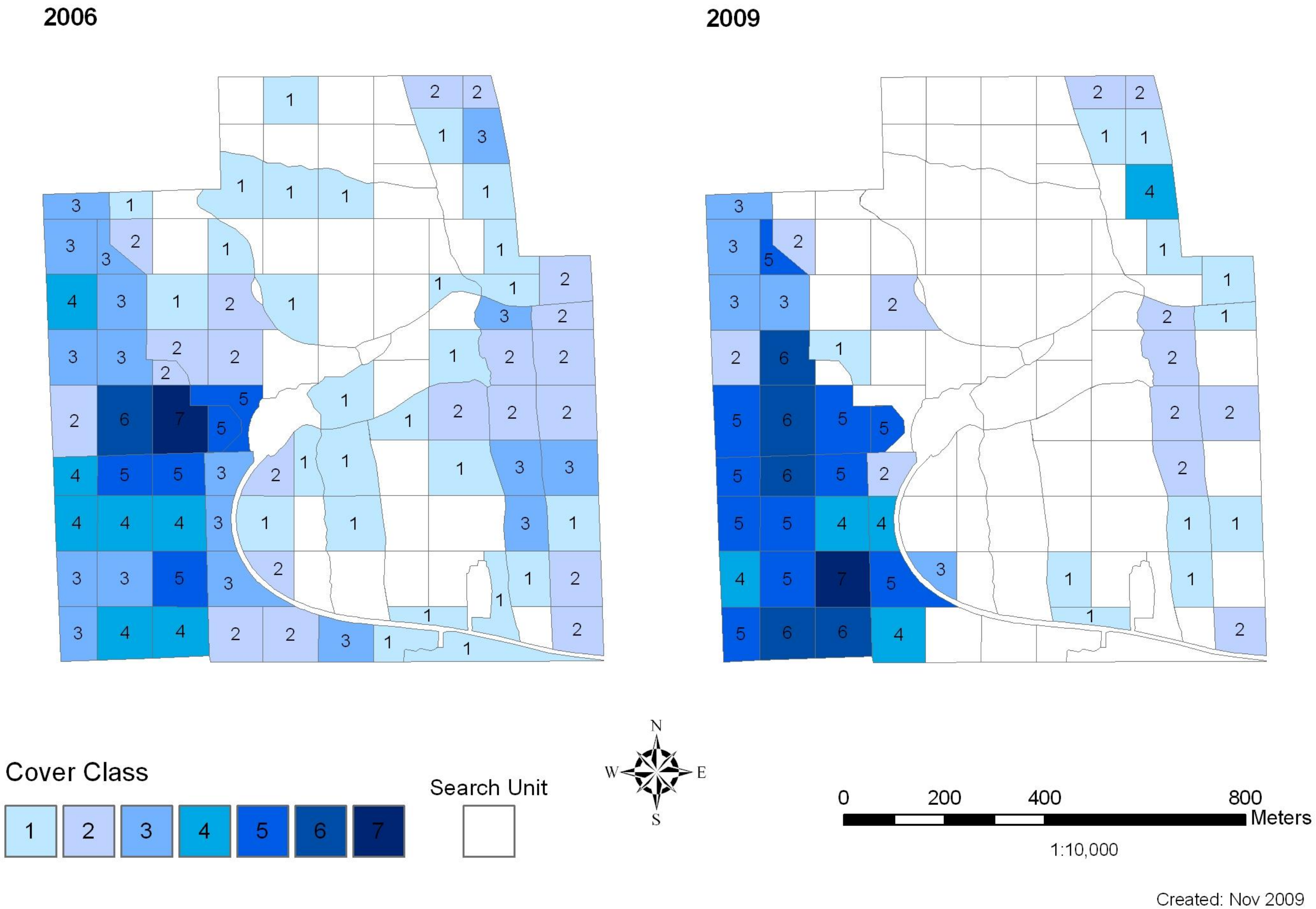

Figure 12. Abundance and distribution of *Melilotus officinalis* (yellow sweet clover) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m^2.

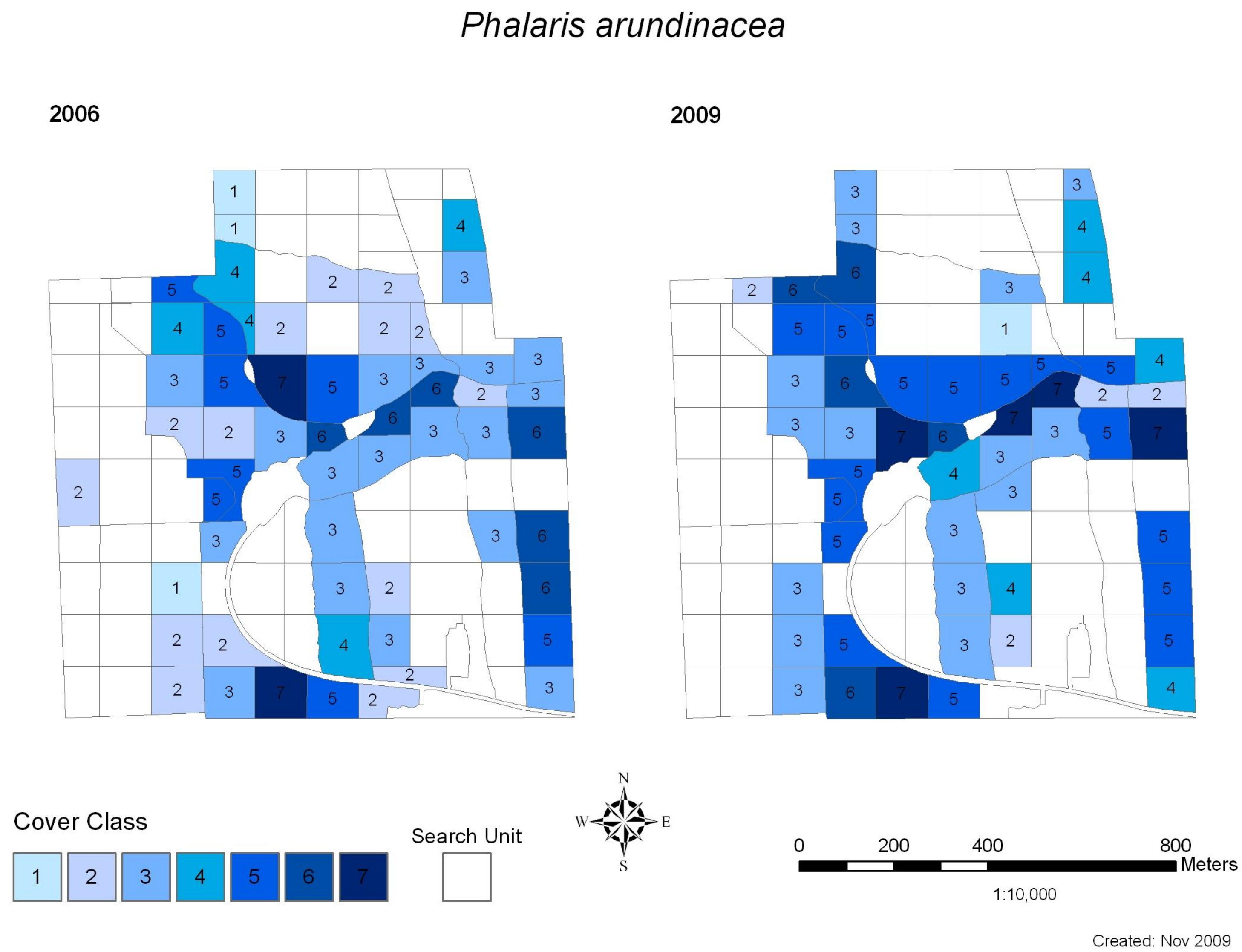

Figure 13. Abundance and distribution of *Phalaris arundinacea* (reed canarygrass) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m^2.

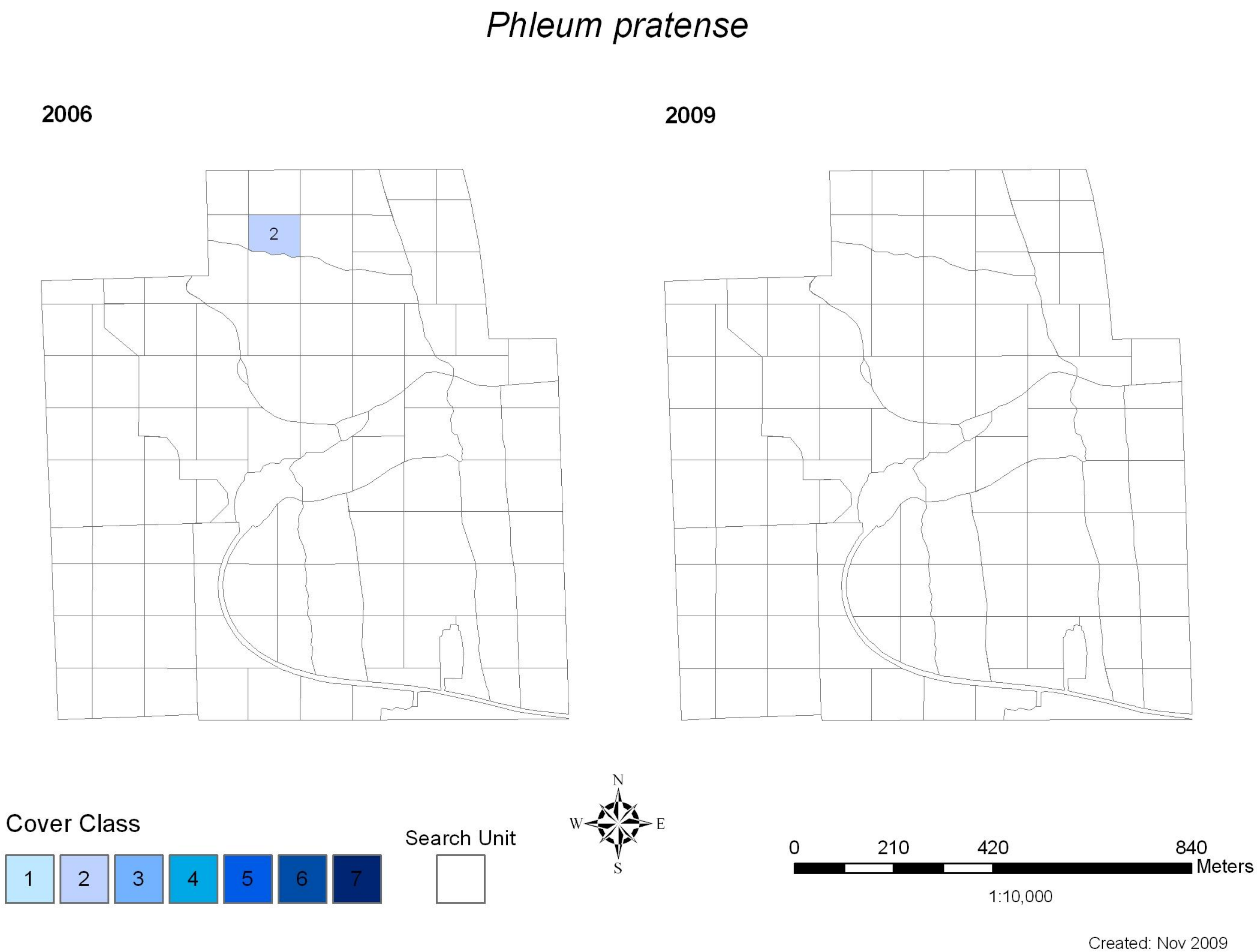

Figure 14. Abundance and distribution of *Phleum pratense* (Timothy) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m²

Poa spp.

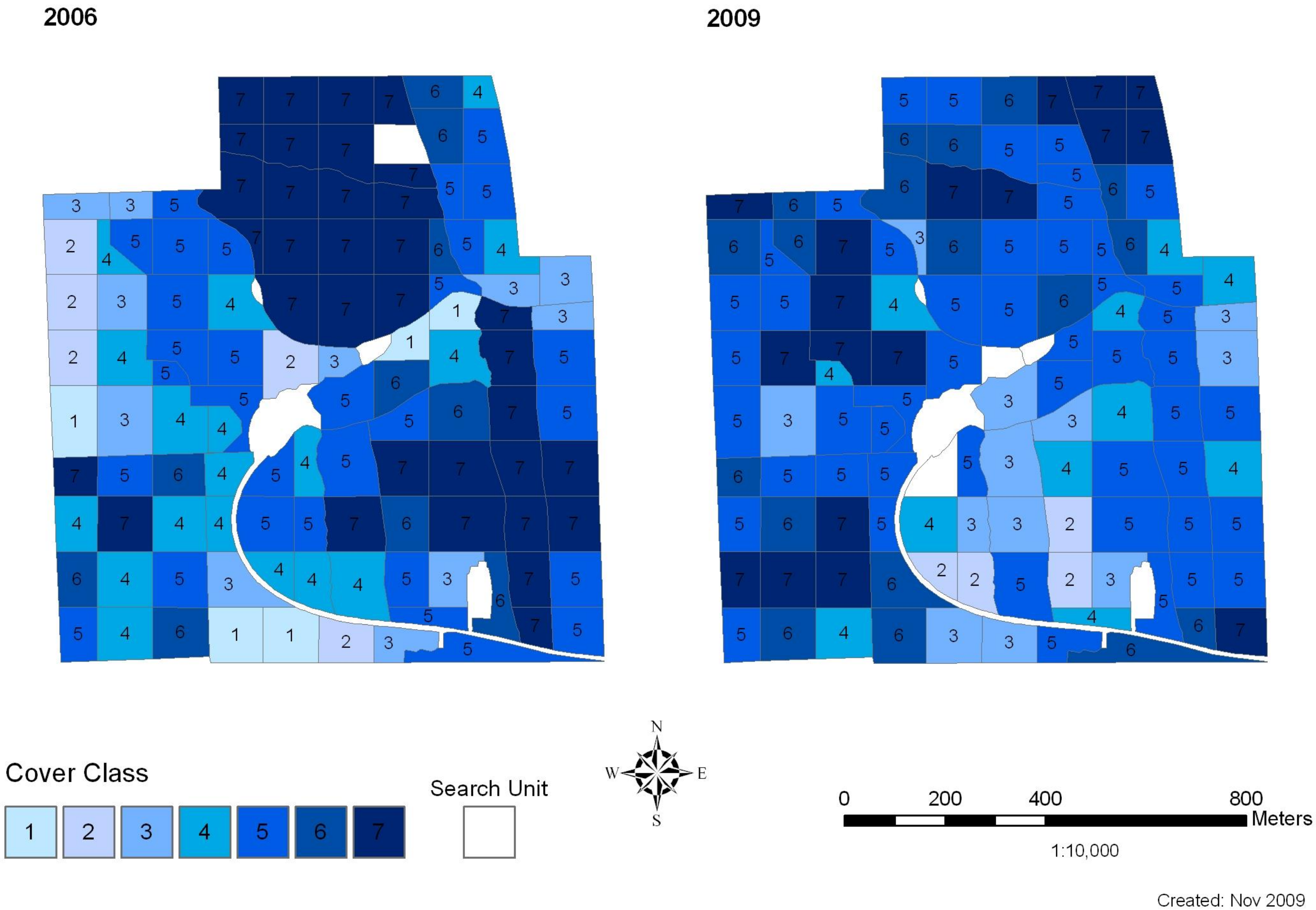

Figure 15. Abundance and distribution of *Poa* spp. (Kentucky / Canada bluegrass) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m².

Rhamnus cathartica

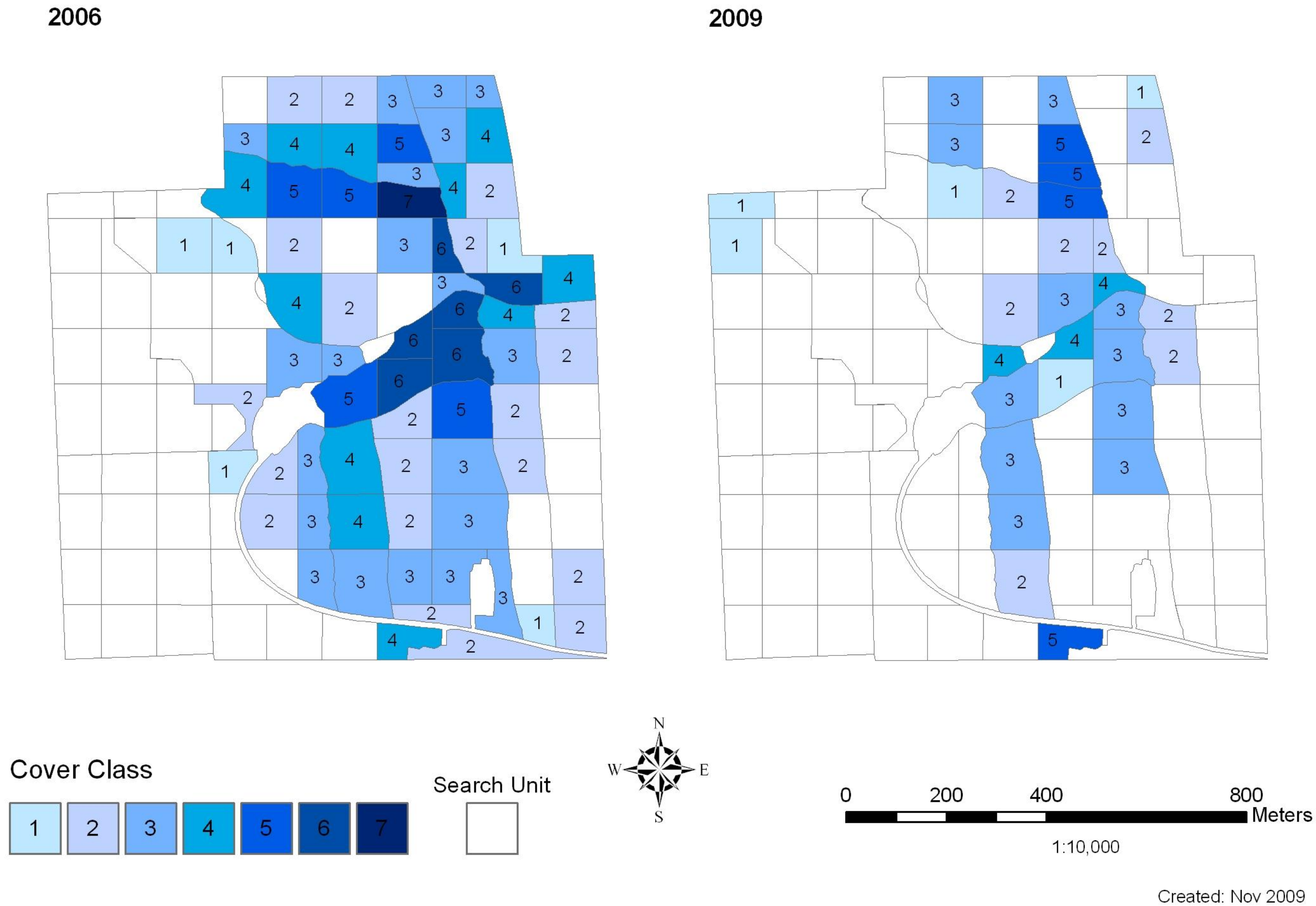

Figure 16. Abundance and distribution of *Rhamnus catharica* (common buckthorn) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m².

Securigera varia

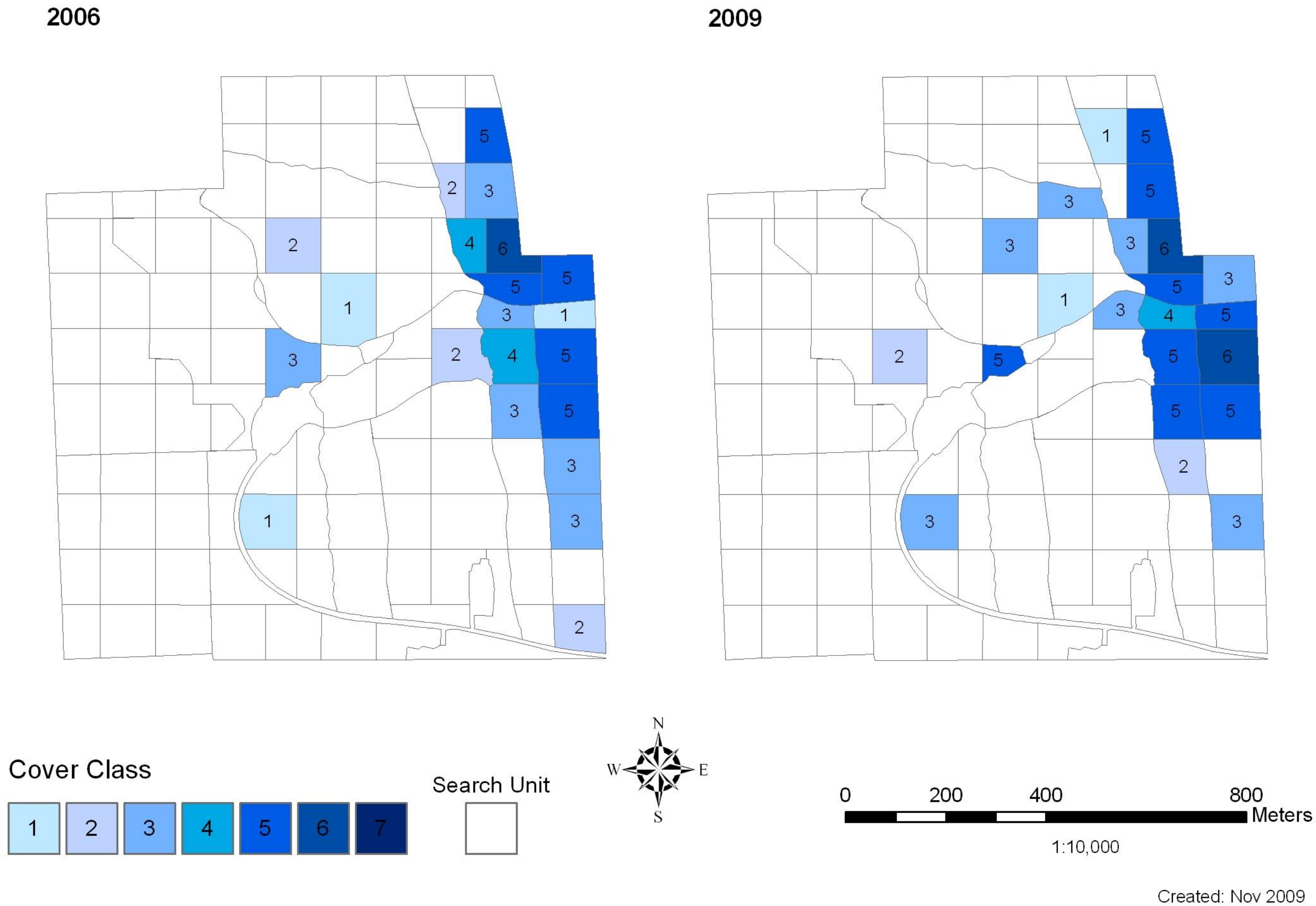

Figure 17. Abundance and distribution of *Securigera varia* (crown vetch) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m^2.

Solanum dulcamara

Figure 18. Abundance and distribution of *Solanum dulcamara* (climbing nightshade) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m².

Sonchus arvensis

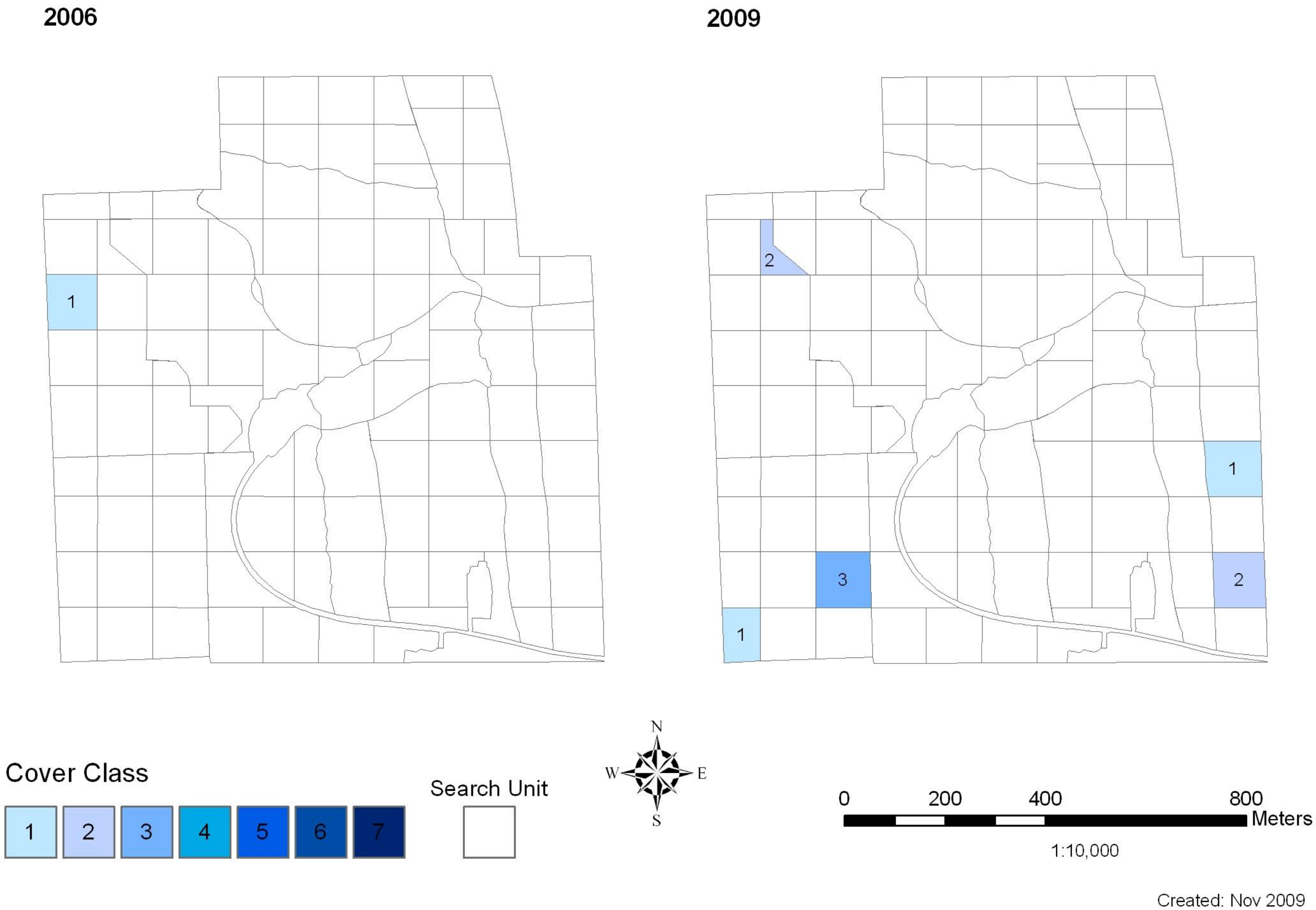

Figure 19. Abundance and distribution of *Sonchus arvensis* (field sowthistle) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m².

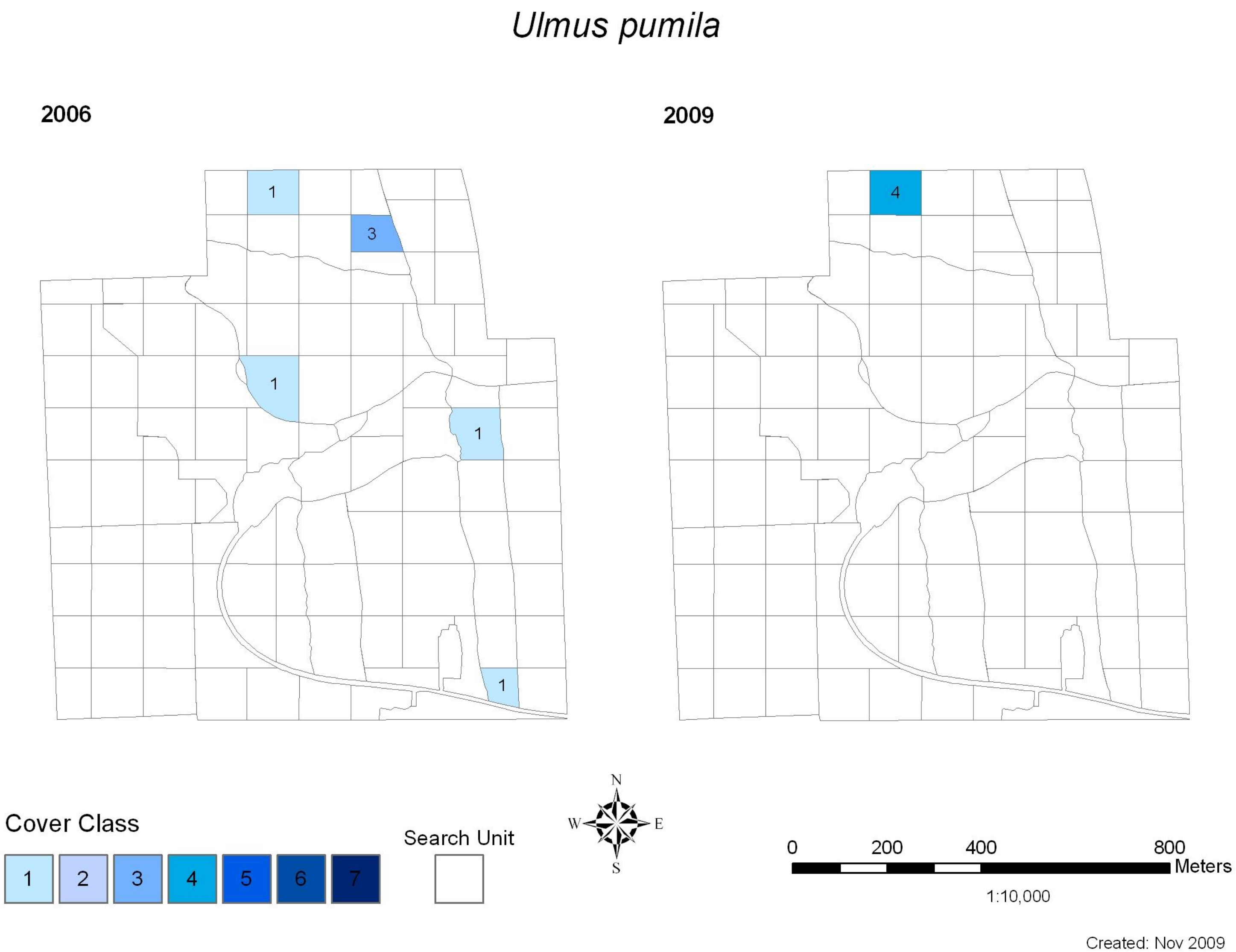

Figure 20. Abundance and distribution of *Ulmus pumila* (Siberian elm) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m^2.

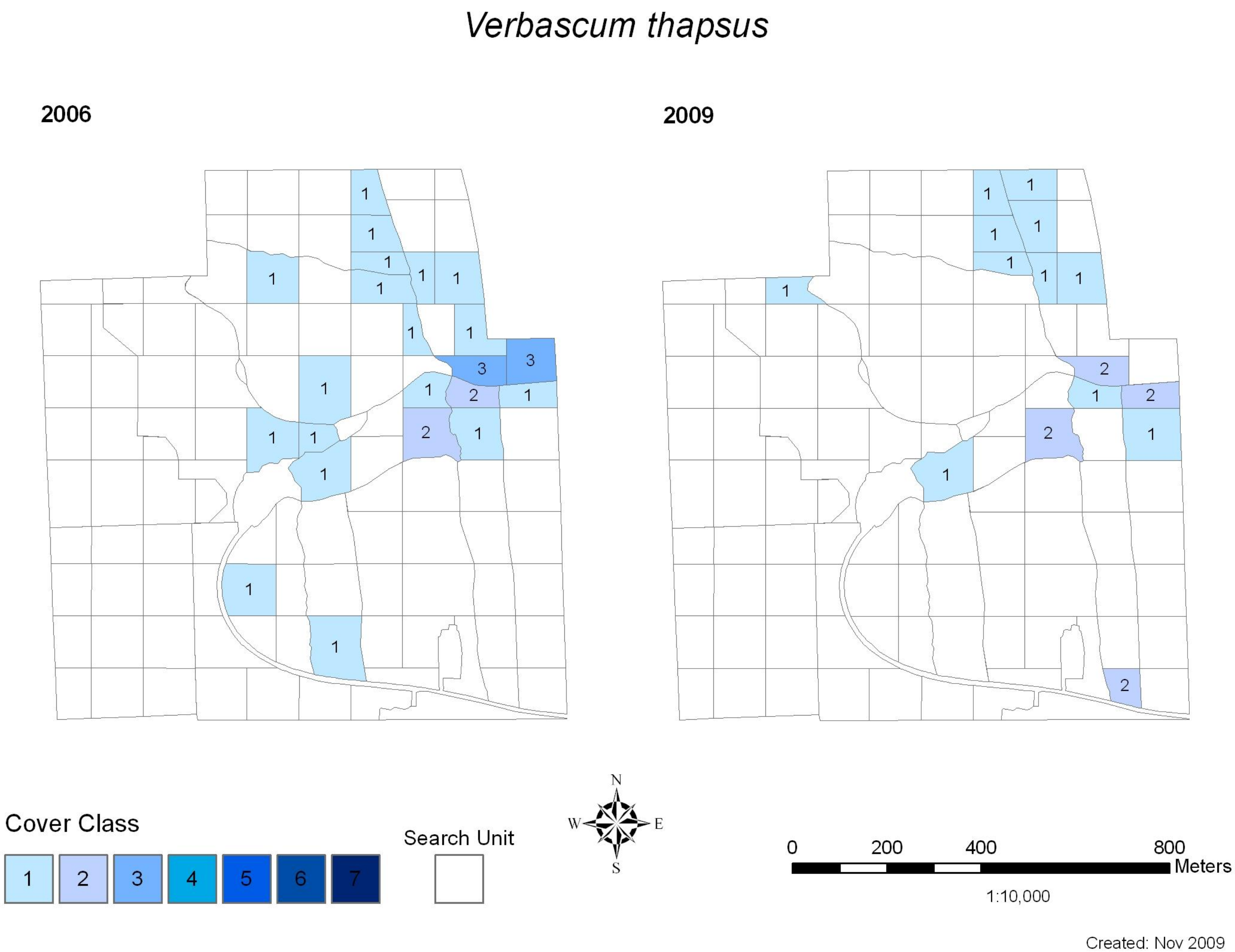

Figure 21. Abundance and distribution of *Verbascum thapsus* (common mullein) at Pipestone National Monument, 2006 and 2009. Cover classes are as follows: 1=0.1-0.9 m^2, 2=1-9.9 m^2, 3=10-49.9 m^2, 4= 50-99.9 m^2, 5=100-499.9 m^2, 6= 499.9-999.9 m^2, and 7 ≥ 1,000 m^2.

The Department of the Interior protects and manages the nation’s natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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U.S. Department of the Interior

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